AUTOMATIC GENERATION OF COMPLEX SIMULATION MODELS OF BUILDINGS WITH SOLAR HEATING SYSTEMS

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ABSTRACT
Comprehensive studies of the energy saving potential for buildings will often not be performed in a design phase - especially not for renovation projects. There may be several reasons for that but it may often be related to the amount of time needed to create models of the buildings and plants. The paper describes a method for auto-generation of complex simulation models for existing, documented and validated simulation programs. An automatic model generator has been developed for Danish conditions and programs. The auto-generation of complex models is based on statistical information and may rather easily be transformed to other countries and simulation programmes. Auto-generation of simulation models reduces/eliminates the user influence - leading to more consistent simulation results.

INTRODUCTION

It is possible to extend the life-time of most buildings through renovation. Renovation of existing buildings in Denmark often includes an energy retrofit, eg insulation of cavity walls, exchange of windows and maybe installation of passive and active solar devices. Passive solar energy applications and active solar heating systems for space heating are often installed without any exact knowledge of the amount of energy being saved, but rather with the idea that *"some energy must be saved"*.

There are multiple reasons for not carrying out comprehensive studies of the energy savings in the actual buildings, but the main reason is often the time necessary to create good models of the building and the plant.

The aim of the described project is to increase the utilization of solar energy by developing a method and a tool for automatic generation of model files for the Danish simulation tools *tsbi3* (building simulation) and *Kviksol* (simulation of active solar heating systems) - both documented and validated (Johnsen and Grau, 1994, Lomas et al 1994, Nielsen, 1993a-d and 1995). The model files are generated from 6-14 user-given building parameters and 5-7 user-given plant parameters. Based on the user-given parameters combined with statistical information on the Danish building tradition, the building regulations from 1850 till today and information on feasible solar heating systems, two model files are created. The models created are valid for multi-storey residential buildings with an active solar heating system for space heating and/or preheating of domestic hot water. The simulations of the building and the active solar system are not integrated in one program but are running in parallel, exchanging data at each time step.

The main reason for concentrating on multi-storey residential buildings is, that during the last years construction of new buildings has decreased in Denmark, while renovation of existing buildings has increased. The tendency of renovation rather than construction of new buildings is expected to continue over the coming years. The residential buildings use approximately 50% of the total energy consumption for space heating in Denmark.

THE APPLIED SIMULATION PROGRAMMES

It was from the start of the project decided to use existing, validated and documented simulation programmes rather than trying to develop a new simulation environment.

In Denmark the most used program for simulation of energy consumption and indoor climate in buildings is *tsbi3* (thermal simulation of buildings and installations, 3. generation). *tsbi3* is a dynamic, multi-zone building simulation program, running on a DOS computer. The program has recently been extended with a module for simulation of solar walls (Wittchen, 1993 and 1994), but it has no facility to simulate the utilization of active solar energy (ie solar heating systems for domestic hot water and/or space heating).

The most commonly used program for simulation of active solar heating systems in Denmark is *Kviksol*. *Kviksol* is a simulation program running on a DOS computer. One major reason for the widespread use is, that governmental subsidies for active solar heating systems are calculated using the performance simulated by *Kviksol*. Another reason is that simulation of a whole year is performed within a few seconds.

AUTOMATIC GENERATION OF MODELS

A model generator for automatic generation of models of buildings and active solar heating systems for *tsbi3* and *Kviksol* has been developed. The model generator is at the moment being validated - or rather compared to models made by experienced *tsbi3* and *Kviksol* users. The models are auto-generated from very few essential user-given input parameters combined with statistical information on the Danish building stock and typical, economically acceptable configurations of active solar heating systems.

Based on a comprehensive study, the Danish residential building stock has been divided into 5 categories characteristic to specific periods. Within these categories the buildings are very similar with regard to construction - walls, roof, floor, windows, etc - and geometry - floor area, depth of the dwellings, height of the rooms, number of rooms, roof tilt, etc. The five building categories may briefly be characterized as follows:

1850-1929: Massive brick walls. Wooden floor partitions. Windows: single glazed units. A typical building is a 5-storey building including utilized attic. Tilt of roof: 45°.

1930-1959: Brick cavity walls. Concrete floors. Windows: double-glazed units in separate frames. A typical building is a 3-storey building with balconies. Tilt of roof: 30°.

1960-1976: Prefabricated concrete cavity walls with insulation. Concrete floor slabs. Windows: double-glazed sealed units. A typical building is a 3-storey building with balconies. Tilt of roof: 10°. The first national building code was introduced in the beginning of the period.

1977-1995: Brick/concrete walls with insulation. Concrete hollow core floors. Windows: double-glazed sealed units. A typical building is a 3-storey building including utilized attic. Tilt of roof: 45°. Extended demands on insulation were introduced in the beginning of the period.

1996- : New more rigorous demands for the insulation standard. The buildings should eg at least have double-glazed sealed units with low emission coating or triple-glazed sealed units in the windows. Tilt of roof: 45°.

Based on this statistical information it is possible to generate complete building models with only 6 user-specified parameters if no previous energy retrofit has been carried out on the building - figure 1. The six basic parameters are:

- *year of initial construction* for determination of the constructions and geometry of the building ie materials of internal and external walls, area and type of windows, geometry of the apartments, slope of the roof, etc,
- *orientation* of main facade,
- *surroundings* giving the general skyline causing shading from external obstacles,
- *built-up area* of the building,
- *number of stocks* gives, together with the built-up area, the overall geometry of the building,
- *number of apartments* giving the number of thermal zones of the building.

If an energy retrofit has been performed on the building, up to 7 additional user-defined parameters may be necessary as shown in figure 2. The 7 parameters are:

- design of the *ventilation system* - exhaust or balanced with heat recovery,
- indication of *balconies* having been glazed,
- the temperature in the *basement,* - though not an energy saving measure, important to the simulated energy consumption and storage loss.
- type of *windows* if exchanged,
- insulation of *cavity walls,*
- *additional insulation* on the roof,
- *additional insulation* in/under the floor above the basement.

The generated building model has 6, 12 or 18 thermal zones (figure 3), depending on the number of storeys of the building (1, 2 or N storeys). If the building has more than 2 storeys the model has 18 thermal zones, the intermediate storeys are replicated in the output but only simulated once.

The model of the active solar system is created from 5-7 user-defined parameters - figure 4:

- the *purpose of the system,* ie is it a system only for preheating of domestic hot water or is it a combined system for domestic hot water production and space heating,
- which *type of system,* within the two above-mentioned categories,
- the *collector area.* The program gives a warning if the collector area is larger than what is normally assumed to be feasible or exceeds the available roof area. For domestic hot water systems the model generator proposes a feasible area,
- the *collector type,* ie the efficiency of the solar collector,
- the *temperature of the cold and hot* domestic water.

If a system for space heating has been chosen:

- the *heating system,* ie the flow/return temperatures for the heat emitters.

If a system for space heating with delivery to a fixed temperature (SH 4 - figure 5):

- the *fixed temperature* (eg swimming pool or district-heating) to which the active solar heating system is delivering energy.

Essential parameters for simulation of the performance of the solar heating system as daily hot water demand, orientation and tilt of the solar collector, size of the storage, heat exchangers, etc are calculated based on the user-defined parameters given for the building and the solar heating system combined with statistical information (Jensen, 1995).

By reducing the number of user-defined parameters, the user's influence on the simulation results is considerably reduced. This will lead to more consistent simulation results compared to the situation where the users themselves create the models of the buildings from scratch - especially when different persons are modelling the same building. The use of a model generator has further the advantage, that it is possible to validate major parts of the input parameters to the simulation programmes, eg the connections between the zones of the model are correct.

USE OF THE MODELS

It is often very difficult to obtain valid information on an older existing building eg drawings or information of construction details of the building. The auto-generated models may, therefore, often be as close to the reality as models created based on the available information of the actual buildings. The models may thus form an easy first estimate of the potential energy savings in the early stage of a building project leading to renovation projects aiming at increased energy savings.

If the models for some reason are too far away from reality or if there is a desire to perform some parametric analyses, the models are easily modified using the interfaces of the programmes or traditional ASCII editors. This is easy, as the time consuming work of creating the skeleton of the models and the check of the zone connections has already been undertaken. As the consultants are familiar with the simulation programmes, it is not a problem to modify the auto-generated models if necessary.

PARALLEL SIMULATIONS

Instead of combining the two simulation programmes in one simulation program it has been chosen to make it possible to run the two programmes in parallel, ie exchanging data at each time step. In this way it is possible to simulate the interaction between the building and the solar heating system, and it has the advantage that future developments of the two programmes can be used directly as the programmes are independent of each other and created by different organizations.

Information about the energy requirements for space heating is transferred from the building simulation program to the active solar simulation program at each time-step, while the available energy for space heating is fed back to the building simulation program - figure 6.

The execution of the programmes and the handling of the output from the programmes are performed by the model generator. This further decreases the time needed to model and simulate the performance of buildings with passive and active solar heating systems.

CONCLUSIONS

The conclusions from the project are:

* it is possible to auto-generate complex models of buildings and active solar heating systems with a reasonable accuracy from a very limited number of input parameters.

* the time required for preparing acceptable models of buildings and solar heating systems is reduced to a minimum.

* the influence of the user on the generation of the models has been reduced to a minimum, which will lead to more consistent simulation results.

* it is not necessary to have detailed information of the building and the solar heating system in order to have a first impression of the possible energy savings from a energy retrofit.

* the models may later easily be edited using the interfaces of the programmes or traditional ASCII editors eg in order to perform parametric analyses or to modify the models if in some way the auto-generated models are too far from reality.

It is hoped that a major result of the project will be, that detailed energy analyses using simulation tools will be performed more often in the early stage of building renovation projects which will lead to increased energy savings and to increased utilization of solar energy.

The above-described concept is developed for Danish conditions and programmes, but the auto-generation of complex models based on statistical information may rather easily be transformed to other countries and simulation programmes especially if it is possible to divide the building stock in a limited number of typical categories.

ACKNOWLEDGEMENTS

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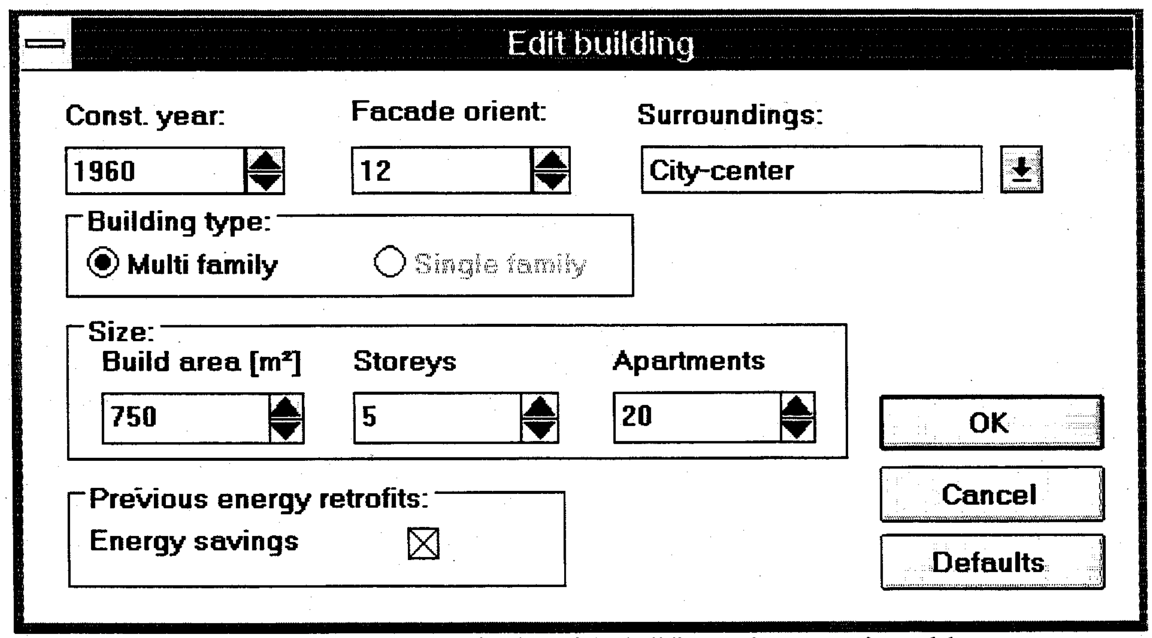

Figure 1 User interface for the specification of the building to the automatic model generator.

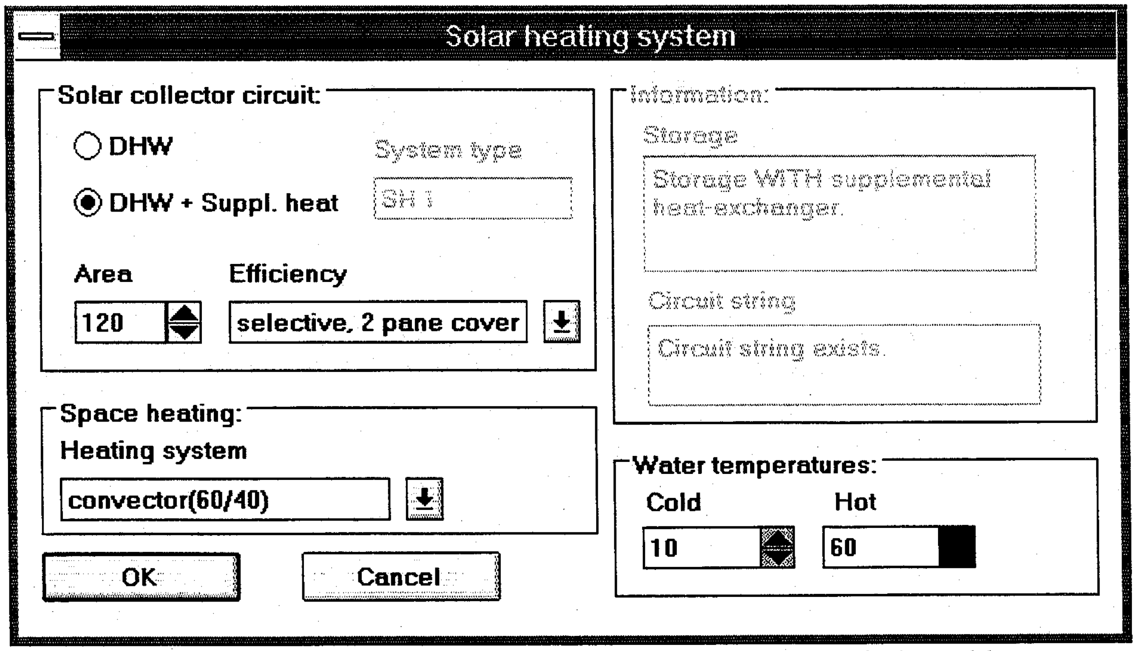

Figure 4 User-interface for specification of the active solar heating system in the model generator.

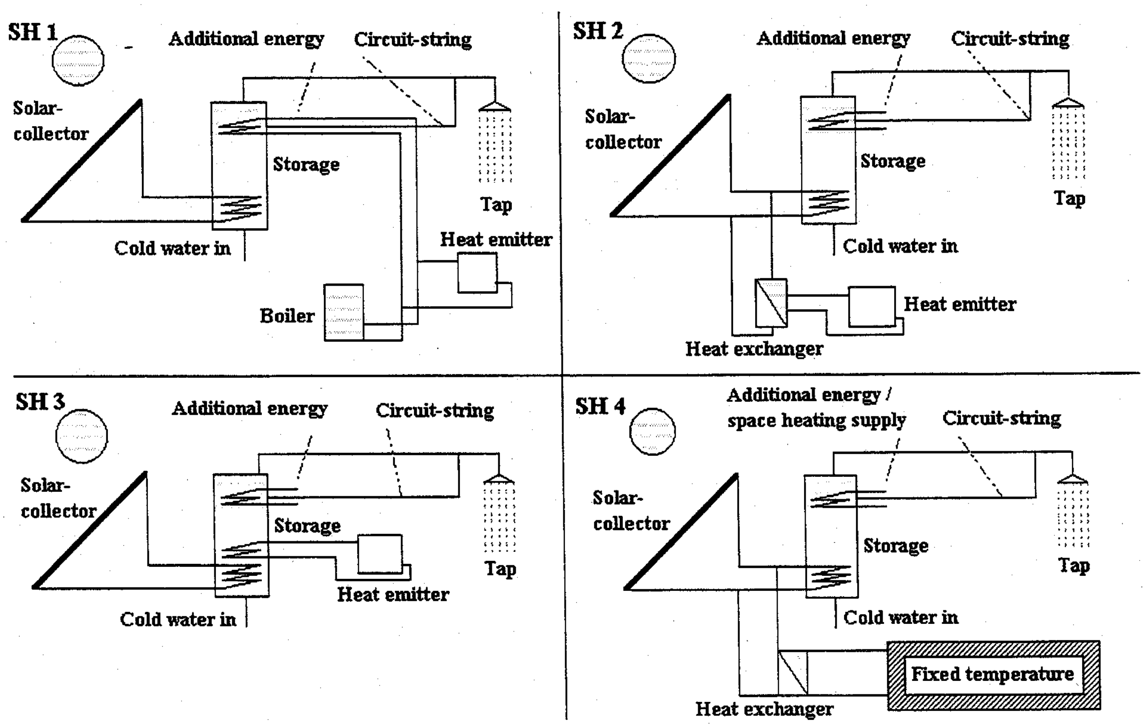

Figure 5 The 4 types of active solar heating systems for space heating to model and simulate within the automatic model generator environment.

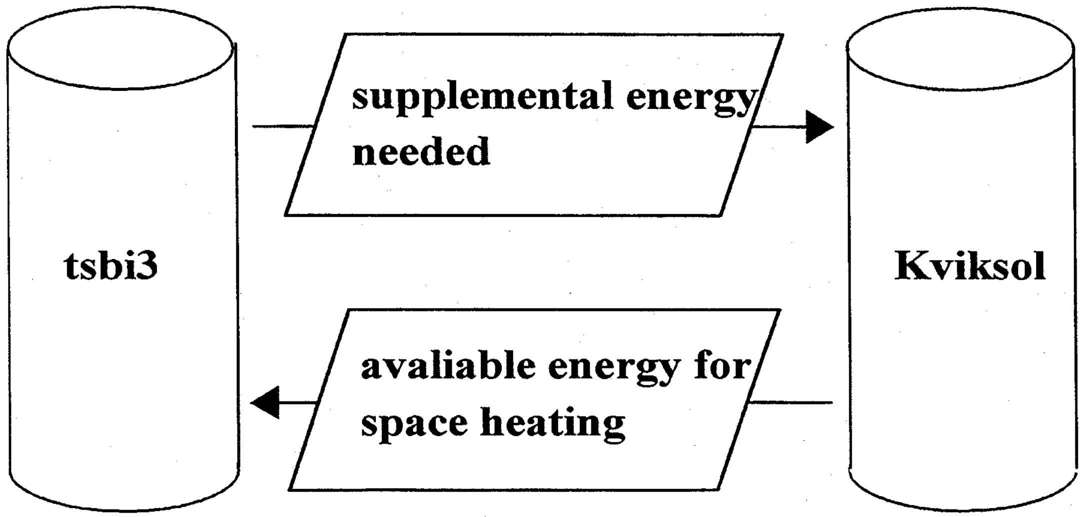

Figure 6 Data-exchange between *tsbi3* and *Kviksol* at each time-step in the parallel simulation.